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Rapid Protium-Deuterium Exchange of 4-Aminopyridines in Neutral D₂O under Microwave Irradiation

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Abstract: 4-Aminopyridines undergo surprisingly rapid and highly-selective H/D exchange at C-2 and C-6 in neutral D₂O upon microwave irradiation at only 190 °C for 2 h in a sealed vessel. This method contrasts and complements acid-mediated H/D exchange, requires no catalyst and is appropriate for the synthesis of deuterium isotopologues of *N*- and *C*-substituted 4-aminopyridines and a benzofused (quinoline) analogue.

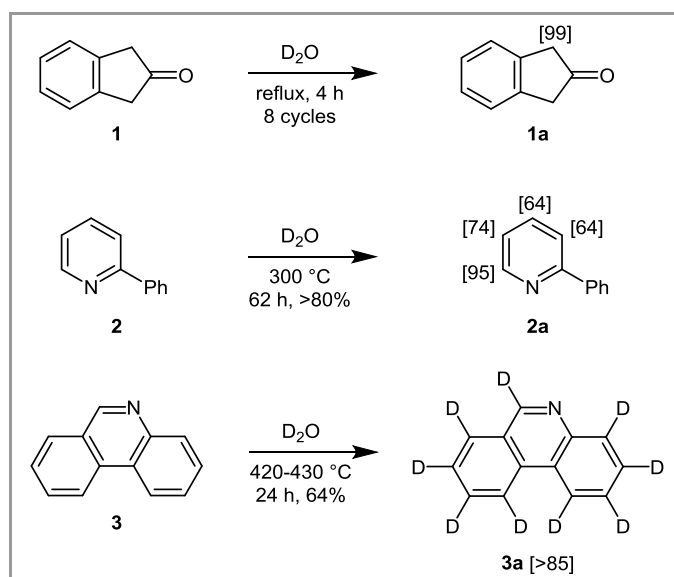
Key words: deuteration, heterocycles, microwave synthesis

The demand for compounds multiply-labeled with stable isotopes has increased dramatically in recent years.^{1,2} Deuterated derivatives are valuable as internal standards for quantifying human and animal pharmacokinetic and metabolism experiments in drug development, as well as for mechanistic probes to determine reaction pathways. Generally speaking, deuterated standards exhibit similar physical and chemical properties to their non-deuterated isotopologues, such as ionization behavior and LC retention times, but differ on account of their mass difference. If this is large enough to separate signals from natural isotope patterns, quantitative analysis is possible.³ Furthermore, deuterated drug isotopologues may be unexpectedly nonobvious in patent law,⁴ differentiating these compounds from prior art and thus making them essential targets for study.

A number of strategies are available for the preparation of compounds bearing multiple deuterium labels.⁵⁻⁷ Firstly, it may be most appropriate to carry out the synthesis using isotopically-labelled precursors. This has the advantage of being predictable, by comparison to the 'natural' isotopologue, but can be time consuming and may require expensive reagents and/or the development of additional sequences. An alternative approach, protium-deuterium exchange of the target molecule or late-stage intermediate, has the potential to be more rapid, efficient and cost-effective. This method removes the need for further developmental work, but must be capable of introducing multiple deuterium atoms in an efficient and predictable fashion.³ H/D exchange is a valuable analytical tool in its own right in protein dynamics^{8,9} and can serve as a useful model for analytical techniques involving protium-tritium exchange.^{1,10,11}

As a synthetic tool, H/D exchange experiments received intensive study in the 1960's and 70's,^{5,6} leading to a number of advances in pH-dependent and metal-catalyzed processes.¹² With the recent development of higher performance mass spectrometers, and a renaissance of interest in C-H bond activation,¹³ a plethora of H/D exchange methods has now emerged, some using C-H activation technology.¹⁴ Whilst for some substrates, metal-mediated methods are required,² for others it is possible to use the autoprotolytic equilibrium of D₂O in the absence of any catalyst. However, this approach

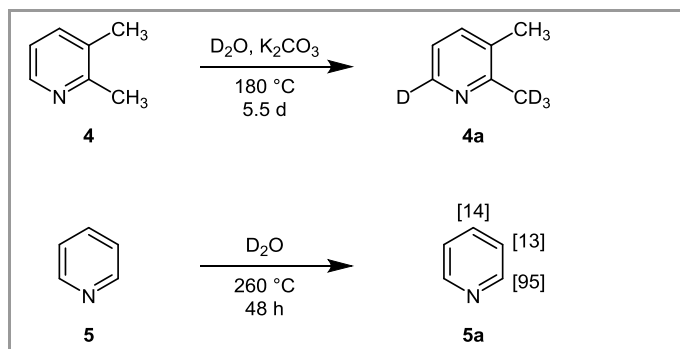
often requires multiple cycles (for example in the synthesis of *d*₄-indanone **1a**),¹⁵ prolonged reaction times¹⁶ or extreme conditions, such as the use of an autoclave in supercritical media at 420–430 °C for the synthesis of phenanthridine **3a** (Scheme 1).¹⁷ Interestingly, H/D exchange of 2-phenylpyridine (**2**) at 300 °C incorporates D to a degree in **2a** at all pyridine positions, but is most rapid at C-6.¹⁶



Scheme 1 Percentage H/D incorporation (in parentheses) under forcing conditions using neutral D₂O¹⁵⁻¹⁷

H/D exchange at the α -position of a number of pyridine derivatives was first observed by Zoltewicz,¹⁸ but has also been described recently. When dimethylpyridine **4** was heated under basic conditions at 180 °C in D₂O for 5.5 d (Scheme 2), exchange at C-6 occurred more rapidly than at the other ring positions, but very forcing conditions were still required.¹⁹ Similarly, pyridine (**5**), when heated to 260 °C for 48 h in D₂O underwent H/D exchange, in high regioselectivity for the α -position, to give dideuterated **5a**. The same process carried out at 200 °C for 24 h gave only 15% D incorporation at this position.¹⁶ Many recent efforts have been directed towards the efficient H/D exchange of pyridine derivatives.²⁰⁻²⁷ A highly site-selective one-step α -labelling of pyridines and *N*-heteroaromatic compounds has been described using deuterium gas and a rhodium or ruthenium catalyst.²⁸ Furthermore, it has been remarked that a 4-pyrrolidino group accelerates H/D exchange at all pyridine positions.¹⁶ With this precedent, we set out to establish a simple one-step method for site-selective

useful synthetic procedure. Aniline (**9**), under these conditions, showed increased incorporation at the *ortho*- and *para*-positions of **9b**, also as expected, and yet essentially the same %D incorporated at *meta*-positions. The observation most worthy of note was that H/D exchange of 4-aminopyridine (**8**) completely reversed under acidic conditions, with high levels of incorporation now observed at C-3 and C-5 (positions activated to electrophilic aromatic substitution) and yet minimal incorporation at the pyridine α -carbons of **8b**. This demonstrated that mechanisms operating in neutral D₂O (Table 1) were distinct from the electrophile-mediated process (Table 2) for this substrate and so were worthy of further optimization as a site-selective method for D-incorporation. Carrying out the H/D exchange in neutral D₂O at lower temperatures (170 or 180 °C) gave 4-aminopyridine (**8c** or **8d**) with much less efficient D incorporation at all positions (Table 1) and so reaction at 190 °C under microwave irradiation in neutral D₂O was adopted as the method of study.



We started by reviewing the H/D exchange of 2-(6), 3-(7), and 4-aminopyridine (8) in neutral D₂O under microwave irradiation at 190 °C for just 2 h in a commercial instrument, comparing the results to H/D exchange of aniline (9) under the same conditions (Table 1). Considerable differences were noted in the efficiency of H/D exchange at different positions across this small series of substrates. For 2-aminopyridine (6), exchange was poorly efficient at all positions under these relatively mild conditions, as might be expected. The reaction of 3-aminopyridine (7) under these conditions was much more selective, with good incorporation at C-2 and yet very low levels of H/D exchange at all other positions, including at C-6. Unfortunately, increasing the reaction time gave no further improvement in D incorporation at C-2 (80%). Remarkably, 4-aminopyridine (8) underwent rapid H/D exchange at the α -positions, even at this relatively low temperature, indicating its unusual high reactivity in the process. By means of comparison, aniline (9) was found to undergo low levels of H/D exchange at ring positions under the experimental conditions. It is noteworthy that contrasting behaviour has been described by Zoltewicz in a study of H/D exchange of 4-amino-2,6-dimethylpyridine, with respect to 2,6-lutidine, under neutral and acidic conditions.^{18c}

Table 1 %D Incorporation after microwave irradiation at 190 °C for 2 h in neutral D₂O^a

Product	C-2	C-3	C-4	C-5	C-6	Yield ^b
2-Aminopyridine (6a)	-	54	52	53	56	72
3-Aminopyridine (7a)	80	-	6	3	12	66
4-Aminopyridine (8a)	98	50	-	50	98	57
4-Aminopyridine (8c) ^c	39	5	-	5	39	52
4-Aminopyridine (8d) ^c	67	17	-	17	67	57
Aniline (9a)	17	14	24	14	17	49 ^d

^a As determined by ¹H NMR spectroscopic analysis after introduction of an internal standard by acetylation (AcCl, K₂CO₃, acetone, RT, 3 h), followed by aqueous work-up.

^b Yield refers to the isolated yield/% of product after microwave irradiation of the substrate in D₂O in a sealed Pyrex™ tube at 190 °C, unless stated otherwise, for 2 h (hold-time) by moderation of the initial magnetron power (300 W), followed by cooling and an acid-base work-up.

^c Microwave irradiation was at a temperature of 170 °C (for **8c**) or 180 °C (for **8d**).

^d Isolated yield% of the product after an aqueous work-up.

Table 2 %D Incorporation after microwave irradiation at 190 °C for 2 h in D₂O in the presence of DCl^a

Product	C-2	C-3	C-4	C-5	C-6	Yield ^b
2-Aminopyridine (6b)	-	94	54	94	54	70
3-Aminopyridine (7b)	96	-	15	3	34	60
4-Aminopyridine (8b)	9	92	-	92	9	56
Aniline (9b)	57	12	45	12	57	61 ^c

^a As determined by ¹H NMR spectroscopic analysis after introduction of an internal standard by acetylation (AcCl, K₂CO₃, acetone, RT, 3 h), followed by aqueous work-up.

^b Yield refers to the isolated yield% of product after microwave irradiation of the substrate in D₂O in the presence of DCl (4 equiv.) in a sealed Pyrex™ tube at 190 °C for 2 h (hold-time), by moderation of the initial magnetron power (300 W), cooling, and an acid-base work-up.

^c Isolated yield% after aqueous work-up.

Given the high site-selectivity for H/D exchange of 4-aminopyridine (**8**) in neutral D₂O, a range of substrates was investigated under the newly-found set of conditions²⁹ (microwave irradiation at 190 °C, 2 h) to estab-

lish the scope of the method, changing the nature of the substituent, its position, and even the heterocycle (Table 3). For some substrates, reaction in both the presence and absence of DCI was investigated to see if a reversal of the regioselectivity was observed. It was found that *N*-alkyl groups exhibited minimal side-chain exchange under these conditions (entries 3-7) and their presence slightly retarded H/D exchange at C-3 and C-5, presumably as a consequence of steric effects. Excellent incorporation at C-2 and C-6 (95-98%) was observed for **10-12** under neutral conditions, also with high levels of regiocontrol (entries 3, 5 and 6). 4-Aminoquinoline (**13**) showed similar behavior (entry 8), although the efficiency of incorporation at C-2 in **13a** (89%) was reduced slightly with respect to its pyridine counterpart **8a** (98%). D incorporation in 4-pyrrolidinopyridine (**12b**) and 4-aminoquinoline (**13b**) was seen to reverse by carrying out the procedure in the presence of DCI (entries 7 and 9), demonstrating that this method proceeds by a contrasting mechanism and complements acid-mediated exchange. For quinoline products **13a** and **13b**, minimum exchange was noted in the carbocyclic ring under

both sets of conditions. Efficient incorporation was only affected marginally (89%) by the presence of a methyl group, at C-3 in **14a** (entry 10) or at C-2 in **15a** (96%) – the latter also showing efficient incorporation (97%) at C-1' (entry 11). The effect of halogen substituents (**16-18**) did vary with position: with a halogen at C-3 high efficiency (98%) and regioselectivity for C-2 was observed (entries 12 and 13), but the 2-chloride **18** did not exchange efficiently (entry 14) perhaps as a consequence of its reduced basicity. Interestingly, the 3-iodide **17a** exhibited relatively high D incorporation at both α -positions (entry 13; 98 and 75%) whereas the 3-bromide did not (entry 12; 98 and 34%). Finally, exchange in both 4-aminopyrimidine (**19a**) and 2-aminopyrazine (**20a**) was less rapid (entries 15 and 16), the corresponding substrates postulated as being less reactive in the process as a consequence of their reduced basicity (*cf* pK_{aH} 2-aminopyridine 6.86; 4-aminopyrimidine 5.71; 2-aminopyrazine 2.96; 4-aminopyridine 9.17).³⁰ In cases for which H/D exchange was efficient and highly-selective the isolated yield of the product was of preparative value (57-97% yield).³¹

Table 3 %D Incorporation of substituted 4-aminopyridines and related heterocycles after microwave irradiation at 190 °C for 2 h in D₂O in the presence or absence of DCI^a

Entry	Substrate	DCI present	Product	C-2	C-3	C-5	C-6	C-7	C-8	C-1'	C-2'	C-3'	Yield ^b
1	4-aminopyridine (8)	×	8a	98	50	50	98	-	-	-	-	-	57
2	4-aminopyridine (8)	✓	8b	9	92	92	9	-	-	-	-	-	56
3	4-(methylamino)pyridine (10)	×	10a	98	22	22	98	-	-	<4	-	-	91
4	4-(methylamino)pyridine (10)	✓	10b	<4	96	96	<4	-	-	<4	-	-	82
5	4-(dimethylamino)pyridine (11)	×	11a	97	6	6	97	-	-	<4	-	-	97
6	4-pyrrolidinopyridine (12)	×	12a	95	9	9	95	-	-	-	<4	<4	96
7	4-pyrrolidinopyridine (12)	✓	12b	<4	74	74	<4	-	-	-	<4	<4	97
8	4-aminoquinoline (13)	×	13a	89	23	9	<4	<4	9	-	-	-	69
9	4-aminoquinoline (13)	✓	13b	19	98	10	<4	<4	10	-	-	-	74
10	4-amino-3-methylpyridine (14)	×	14a	94	-	8	93	-	-	<4	-	-	97
11	4-amino-2-methylpyridine (15)	×	15a	-	5	8	96	-	-	97	-	-	84
12	4-amino-3-bromopyridine (16)	×	16a	98	-	17	34	-	-	-	-	-	82
13	4-amino-3-iodopyridine (17)	×	17a	98	-	25	75	-	-	-	-	-	93
14	4-amino-2-chloropyridine (18)	×	18a	-	42	30	30	-	-	-	-	-	98
15	4-aminopyrimidine (19)	×	19a	64	-	22	58	-	-	-	-	-	26
16	2-aminopyrazine (20)	×	20a	-	52	17	17	-	-	-	-	-	61

^a As determined by ¹H NMR spectroscopic analysis, after introduction of an internal standard (entries 1-3, 7-15) by acetylation (AcCl, K₂CO₃, acetone, RT, 3 h), followed by aqueous work-up and purification by column chromatography on silica if required; or by reference to a known quantity of dioxane as an external standard (entries 4-6).

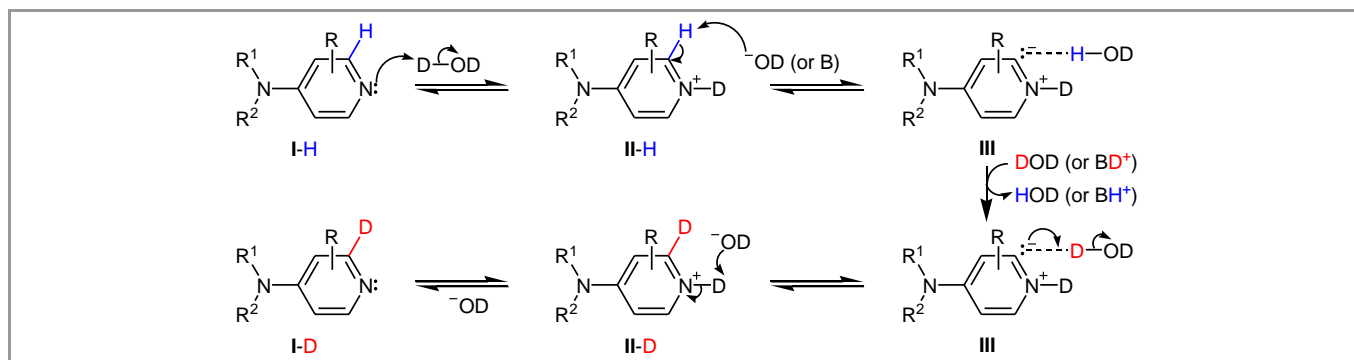
^b Yield refers to the isolated yield^b of product after microwave irradiation of the substrate in D₂O in a sealed PyrexTM tube at 190 °C for 2 h (hold-time) in the presence or absence of DCI (4 equiv.), by moderation of the initial magnetron power (300 W), cooling, and an acid-base work-up.

The fast kinetics of H/D exchange of 4-aminopyridines under neutral conditions, and the high regioselectivity of the process, complements acid-mediated exchange³² and could be attributed to the distinct nature of the operating mechanism. In accordance with the kinetic and mechanistic studies by Zoltewicz on base-catalyzed H/D exchange of *N*-substituted pyridinium ions,^{18d} and exchange of methylpyridines in dilute acid,^{18e} we believe this method could be a specific acid-general base catalyzed process which may be influenced by internal return (Scheme 3). The equilibrium almost certainly involves protonation of the substrate **I** by the solvent (D₂O), giving a pyridinium conjugate acid **II**, which can then be deprotonated by the lyate anion (or substrate **B**) to give pyridinium ylide **III**. Under this premise, the efficiency

of the exchange process for 4-aminopyridines would be attributed to the increased pyridine basicity in general base catalysis, increased stability of the pyridinium ylides **III** upon deprotonation, or a shift from general base catalysis to an internal return limited process, with no significant general base catalysis and slow dissociation of a hydrogen-bonded ylide **III**-conjugate acid complex, as a consequence of the reduced acidity of the pyridinium conjugate acid.^{18d} A profile of reactivity dependent upon aminopyridine basicity and proceeding in equilibrium via pyridinium ylide **III** would, broadly speaking, explain the trends observed in this work (Table 3), such as reduced exchange in 4-amino-2-chloropyridine (**18**), 4-aminopyrimidine (**19**) and 2-aminopyrazine (**20**), but clearly other factors are involved. For example, D

incorporation at C-2 (80%) vs C-6 (12%) (Table 1) of 3-aminopyridine (pK_{aH} 5.98) indicates a role of ylide **III** stability, which could also be in evidence with the high C-2 selectivity for D incorporation in 3-bromide **16a** and low D incorporation (56%) at C-6 for 2-aminopyridine (pK_{aH} 6.86)³⁰; alternative mechanisms could also be in competition. However, no matter what alternative mech-

anisms might be operating, this relatively-mild method under neutral conditions would seem to tolerate a range of 4-aminopyridine basicities, gives quite predictable outcomes and is well-suited to this particular core heterocyclic motif, and a benzo-fused counterpart.



Scheme 3 Possible mechanism of D incorporation in 4-aminopyridine **I-H** involving H/D exchange equilibria of pyridinium ylide **III**

In conclusion, we have demonstrated that 4-aminopyridines undergo rapid H/D exchange at the α -position upon microwave irradiation in D_2O at 190 °C in only 2 h. These neutral conditions tolerate a range of functionality, proceed in a single cycle and require no specialist equipment or added catalyst to provide deuterated isotopologues in reasonable yield. For these substrates the method contrasts from acid-mediated exchange reactions, proceeds via a distinct mechanism (or mechanisms) and provides complementary isotopomers or isotopologues for further study.

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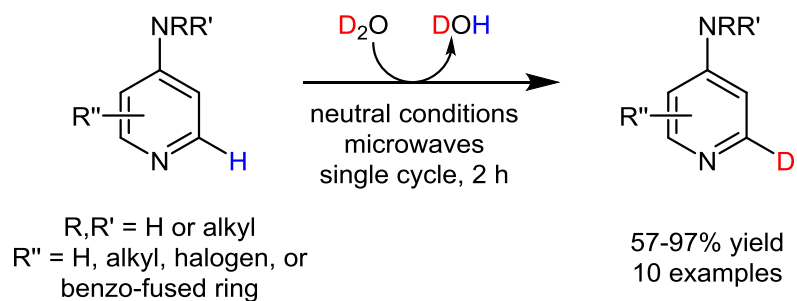
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- (29) **General procedure for H/D exchange of 4-aminopyridines.** A solution of the substrate in D₂O (5 mL) was irradiated in a sealed Pyrex tube at 190 °C for 2 h (hold-time) using a CEM Explorer microwave synthesizer (maximum pressure 150 psi) by moderation of the initial microwave power (300 W). The mixture was cooled in a stream of compressed air and extracted with CH₂Cl₂ (3 × 10 mL). The organic extracts were combined, dried (MgSO₄), filtered and evaporated in vacuo.
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- (31) See Supporting Information for detailed experimental procedures and characterization data. *d*₂-4-Aminopyridine (**8a**) was prepared as a colorless solid; mp 157 °C. IR (neat): 3433, 3144, 3036, 2967, 2262, 1686, 1616, 1583, 1519, 1368, 1299, 1279, 1005, 891, 756 cm⁻¹. ¹H NMR (500 MHz; CD₃OD): δ = 7.95 (0.04H, d, *J* = 5 Hz, 2,6-H), 6.55 (1H, s, 3,5-H). ¹³C NMR (125 MHz; CD₃OD): δ = 155.3 (s, C-N), 148.4 (s, CH isotopologue), 148.1 (td, *J* = 26 Hz, CD), 108.9 (s, CH). MS (EI): *m/z* = 96 (M⁺, 100%), 69 (25), 41 (35). *d*₂-4-(Methylamino)pyridine (**10a**) was prepared as a colorless solid; mp 125 °C. IR (neat): 3396, 3323, 3269, 3030, 2497, 2402, 2232, 1909, 1635, 1564, 1460, 1301, 1250, 1153, 1042, 914 cm⁻¹. ¹H NMR (500 MHz; CD₃OD): δ = 7.99 (0.04H, d, *J* = 7 Hz, 2,6-H), 6.51 (1.56H, s, 3,5-H), 2.80 (3H, s, Me). ¹³C NMR (125 MHz; CD₃OD): δ = 155.5 (s, C-N), 147.9 (td, *J* = 27 Hz, CD), 106.7 (s, CH), 27.8 (s, Me). MS (EI): *m/z* = 111 (52), 110 (M⁺, 100%), 109 (69). *d*₂-4-(Dimethylamino)pyridine (**11a**) (300 mg, 2.45 mmol) was prepared as a colorless solid; mp 113–114 °C; IR (neat): 3286, 3250, 3179, 3045, 2922, 2819, 2236, 1579, 1498, 1350, 1308, 1225, 1068, 993, 750 cm⁻¹. ¹H NMR (500 MHz; CD₃OD): δ = 8.06 (0.07H, m, 2,6-H), 6.63 (1.88H, s, 3,5-H), 3.03 (6H, s, 2Me). ¹³C NMR (125 MHz; CD₃OD): δ = 155.0 (s, C-N), 147.7 (td, *J* = 25 Hz, CD), 106.3 (s, CH), 37.7 (s, Me). MS (EI): *m/z* = 124 (M⁺, 86%), 123 (100), 107 (6), 96 (24), 80 (54), 52 (81), 42 (42). HRMS: *m/z* [M + H] calcd for C₇H₈D₂N₂: 125.1042; found: 125.1043. *d*₂-4-Pyrrolidinopyridine (**12a**) (300 mg, 2.02 mmol) was prepared as a colorless solid; mp 59 °C. IR (neat): 3074, 2961, 2910, 2845, 2230, 1583, 1532, 1478, 1361, 1286, 1246, 1154, 997, 700 cm⁻¹. ¹H NMR (500 MHz; CDCl₃): δ = 8.20 (0.10H, d, *J* = 5 Hz, 2,6-H), 6.36 (1.82H, s, 3,5-H), 3.29 (4H, t, *J* = 6 Hz, 2',5'-H), 2.02 (4H, t, *J* = 6 Hz, 3',4'-H). ¹³C NMR (125 MHz; CD₃OD): δ = 152.4 (s, C-N), 147.5 (td, *J* = 27 Hz, CD), 106.7 (s, CH), 46.7 (s, CH₂), 24.8 (s, CH₂). MS (EI): *m/z* = 150 (M⁺, 85%), 149 (100), 121 (15). HRMS: *m/z* [M + H] calcd for C₉H₁₀D₂N₂: 151.1199; found: 151.1199. *d*₁-4-Aminoquinoline (**13a**) was prepared as an orange solid; mp 155 °C. IR (neat): 3443, 2968, 1683, 1528, 1475, 1339, 1316, 1245, 1009, 917, 751 cm⁻¹. ¹H NMR (500 MHz; CD₃OD): δ = 8.25 (0.11H, s, 2-H), 8.06 (0.91H, d, *J* = 8 Hz, 5- or 8-H), 7.81 (0.91H, d, *J* = 8 Hz, 5- or 8-H), 7.64 (1H, t, *J* = 8 Hz, 6- or 7-H), 7.43 (1H, t, *J* = 8 Hz, 6- or 7-H), 6.62 (0.77H, s, 3-H). ¹³C NMR (125 MHz; CD₃OD): δ = 152.6 (s, C-N), 149.2 (td, *J* = 26 Hz, CD), 147.9 (s, C-N), 129.2 (s, CH), 127.4 (s, CH), 124.0 (s, CH), 121.4 (s, CH), 118.6 (s, C), 102.2 (s, CH). MS (EI): *m/z* = 145 (M⁺, 100%), 144 (15), 118 (13). HRMS: *m/z* [M + H] calcd for C₉H₇DN₂: 146.0823; found: 146.0824. *d*₂-4-Amino-3-methylpyridine (**14a**) was prepared as a colorless solid; mp 106 °C. IR (neat): 3345, 3311, 3164, 2536, 2404, 2367, 2288, 2237, 2194, 1631, 1553, 1436, 1264, 1197, 1042, 877 cm⁻¹. ¹H NMR (500 MHz; CD₃OD): δ = 7.87 (0.06H, s, 2-H), 7.71 (0.07H, d, *J* = 7 Hz, 6-H), 6.57 (0.92H, s, 5-H), 2.08 (2.96H, s, Me). ¹³C NMR (125 MHz; CD₃OD): δ = 153.5 (s, C-N), 148.3 (s, CH isotopologue), 146.4 (s, CH isotopologue), 146.1 (td, *J* = 25 Hz, CD), 116.7 (s, C-C), 108.3 (s, CH), 12.7 (s, Me). MS (EI): *m/z* = 110 (M⁺, 100%), 109 (33), 81 (29). *d*₄-4-Amino-2-methylpyridine (**15a**) was prepared as a colorless solid; mp 98 °C. IR (neat): 3324, 3065, 2911, 2848, 2366, 1638, 1602, 1559, 1495, 1345, 1297, 1261, 985, 705 cm⁻¹. ¹H NMR (500 MHz; CD₃OD): δ = 7.84 (0.04H, d, *J* = 6 Hz, 6-H), 6.43 (0.95H, d, *J* = 2 Hz, 3-H), 6.39 (0.92H, d, *J* = 2 Hz, 5-H), 2.27 (0.08H, m, 1'-H). ¹³C NMR (125 MHz; CD₃OD): δ = 157.3 (s, C-N), 155.7 (s, C-C), 147.5 (td, *J* = 26 Hz, CD), 108.0 (s, CH), 106.6 (s, CH), 21.4 (sepp, *J* = 19 Hz, CD₃). MS (EI): *m/z* = 112 (M⁺, 100%), 111 (22), 110 (11), 83 (22), 69 (23), 41 (25). *d*₁-4-Amino-3-bromopyridine (**16a**) was prepared as an orange solid; mp 70 °C. IR (neat): 3448, 3149, 2925, 2536, 2156, 1707, 1628, 1589, 1502, 1419, 1339, 1270, 1184, 1074, 1013, 823 cm⁻¹. ¹H NMR (500 MHz; CD₃OD): δ = 8.20 (0.02H, s, 2-H), 7.90 (0.66H, d, *J* = 6 Hz, 6-H), 6.70 (0.83H, d, *J* = 6 Hz, 5-H). ¹³C NMR (125 MHz; CD₃OD): δ = 152.3 (s, C-N), 149.6 (td, *J* = 27 Hz, CD), 147.0 (s, CH), 109.5 (s, CH), 105.4 (s, C). MS (EI): *m/z* = 174 (M⁺, 60%), 94 (30), 67 (29). *d*₂-4-Amino-3-iodopyridine (**17a**) was prepared as an orange oil; mp 99 °C. IR (neat): 3421, 3294, 3038, 1639, 1581, 1491, 1412, 1337, 1267, 1185, 820, 725 cm⁻¹. ¹H NMR (500 MHz; CD₃OD): δ = 8.38 (0.01H, s, 2-H), 7.92 (0.25H, d, *J* = 6 Hz, 6-H), 6.68 (0.75H, s, 5-H). ¹³C NMR (125 MHz; CD₃OD): δ = 155.4 (td, *J* = 28 Hz, CD), 154.8 (s, C-N), 147.7 (s, CH), 108.7 (s, CH), 79.8 (s, C). MS (EI): *m/z* = 222 (M⁺, 100%), 221 (30), 127 (15), 95 (23), 67 (22), 40 (20).
- (32) Di Giuseppe, A.; Castarlenas, R.; Oro, L. A. *C. R. Chimie* **2015**, *18*, 713.

Short Title: Rapid H/D Exchange of 4-Aminopyridines in Neutral D₂O

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